

Challenges Facing Design and Analysis Tools

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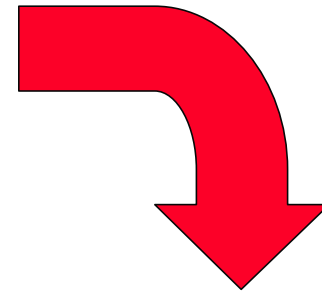


Introduction

- Design is a balance between risks and consequences
- Design of future aerospace systems will need to demonstrate understanding of the system sensitivities in order to meet higher performance requirements and to mitigate risk
- Specific disciplines must interact (at least informally); not work in isolation
- Finite element simulations need
 - to capture more physics
 - to be robust and self-adaptive
 - to exploit available computing infrastructure
 - to be inquisitive and introspective

Challenges in FE Modeling and Analysis

- Mechanics challenges
- Computational challenges
- Risk management
- Decision making



***Future Rapid Modeling
and Analysis Tools***
based on hierarchical and
high-fidelity models
that evolve with the design

Mechanics - Constitutive Models

- Constitutive modeling for modern and emerging material systems need to be developed *and experimentally validated*
 - Different composite architectures
 - Hybrid material systems including sandwich structures
 - Multifunctional materials
 - Damage detection and propagation
 - Embedded health-monitoring systems
 - Self-healing materials
 - Energy-absorbing systems for impact energy management

Modeling Crushable Structural Foams

Percent Crush = 36%



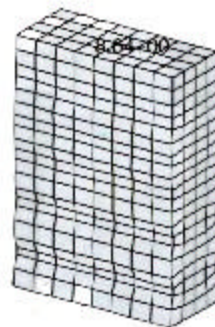
Time = 1.2 ms

42%



1.4 ms

72%



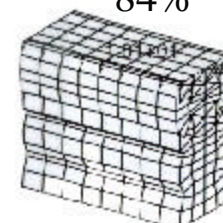
2.4 ms

78%

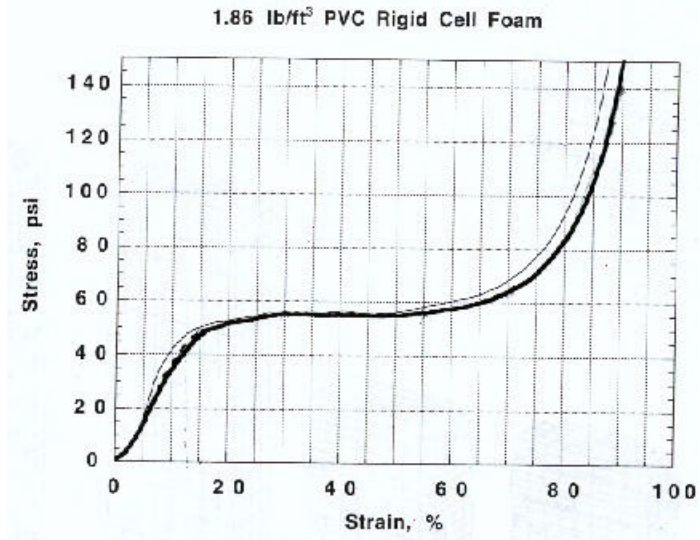


2.6 ms

84%

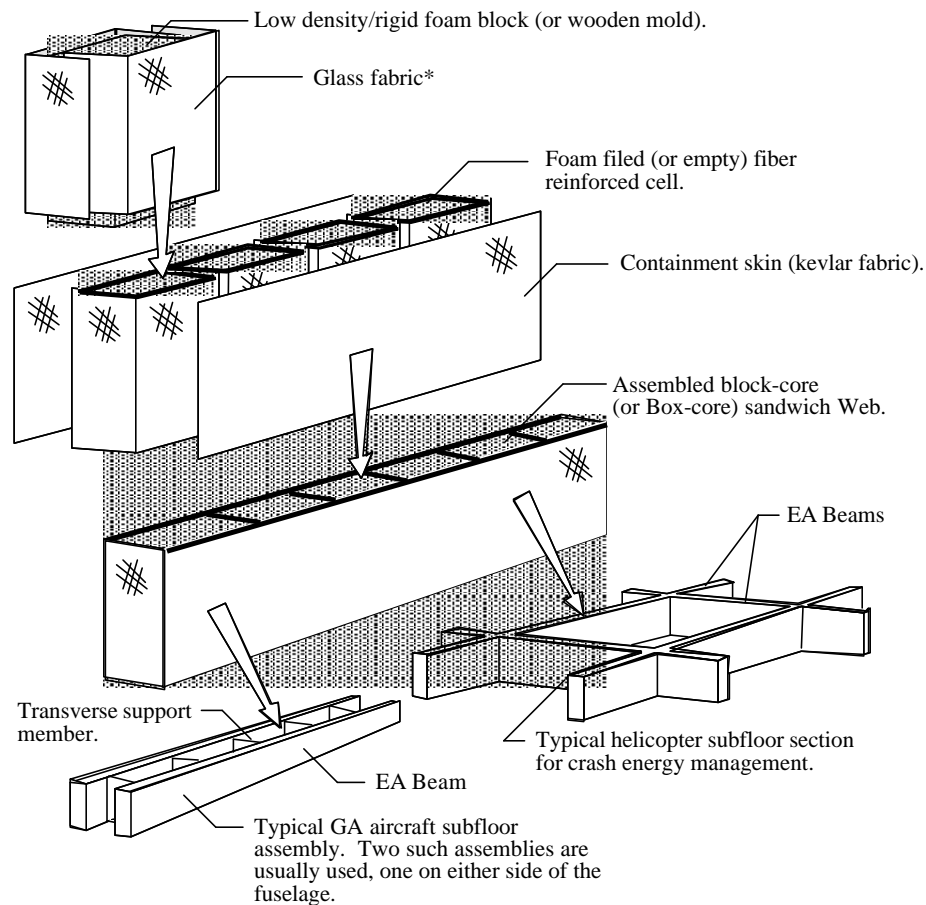


2.8 ms



Energy-Absorbing Structures

Hybrid composite, foam-filled subfloor beam
for crash energy management

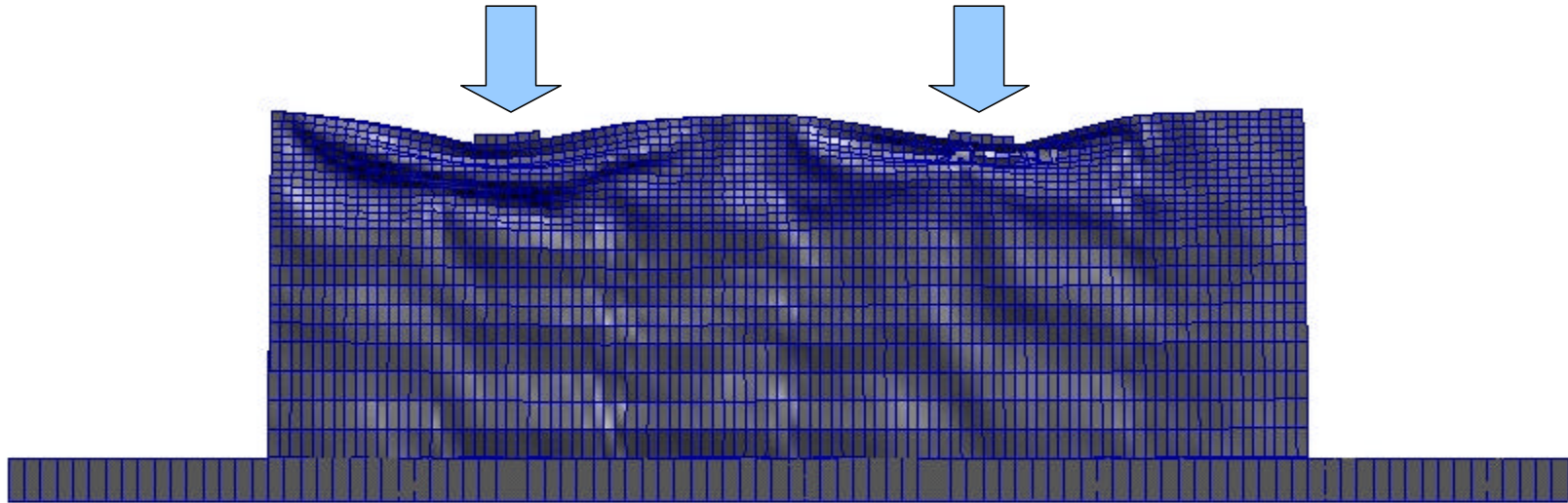


Retrofit for GA Crash Test



Energy-Absorbing Structures

MSC.Dytran Simulation of Subcomponent Test

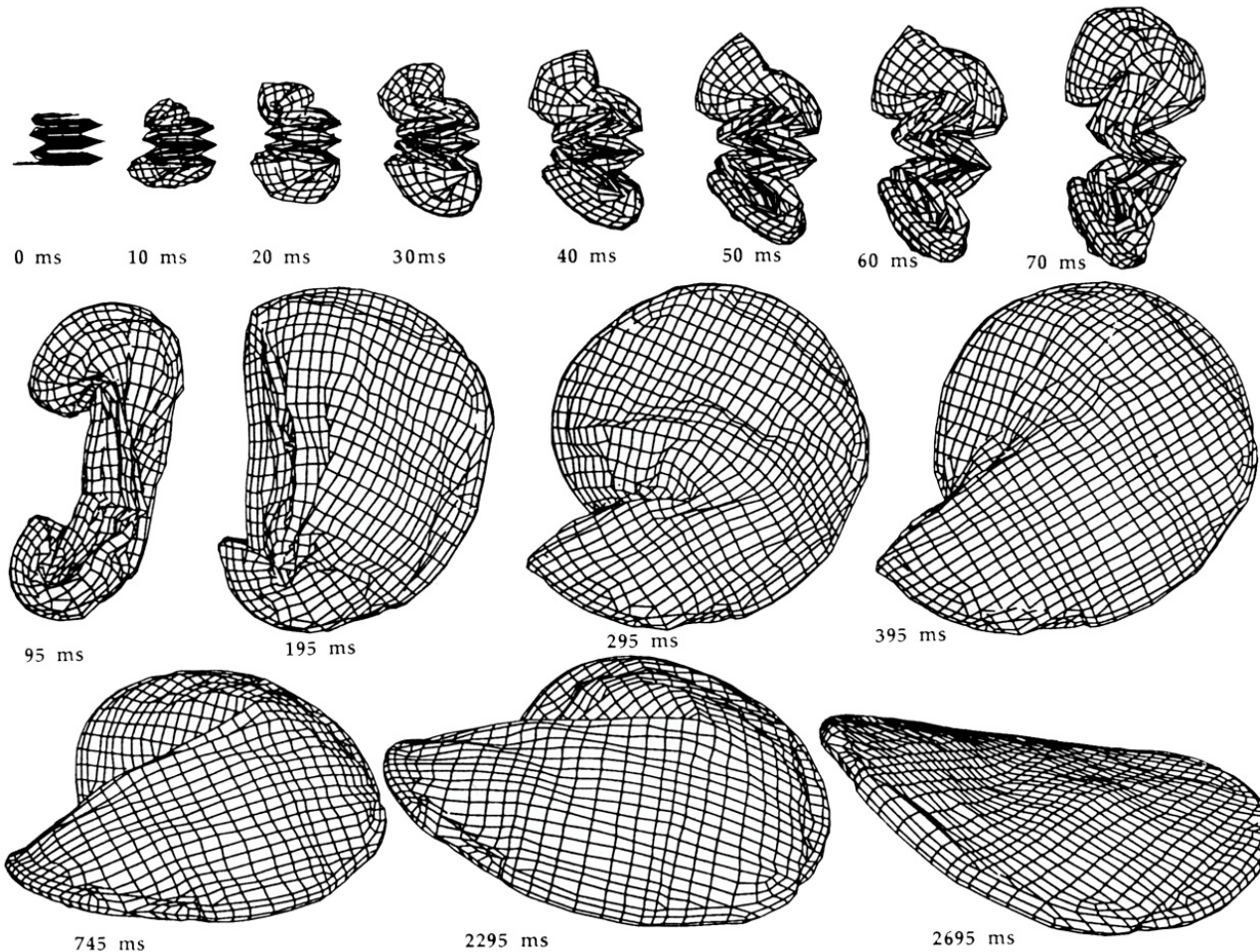


Mechanics - Gossamer Structures

- Gossamer structural mechanics for ultra-thin, wrinkled membranes
 - Very large space structures
 - Limitations of ground-based testing
 - Packaging simulations
 - Folding pattern effects
 - Inflation rates
 - Deployment simulations over long time spans
 - Assessment of off-nominal conditions

Antenna Deployment Simulation

- PAM-CRASH Simulation -



From: Haug et al., "The Numerical Simulation of the Inflation Process of Rigidized Antenna Structures," Proc. Int'l. Conf.: Spacecraft Structures and Mechanical Testing, The Netherlands, 1991, pp. 861-869.

Mechanics - FE Technology

- Extend modeling paradigm beyond only low-order FE
- Extend analysis paradigm beyond linear stress and normal modes analyses
- Fully understand the FE modeling approximations and what it will (*and will not*) predict; what are the limits of the approximations within the model
- Incorporate multiple fidelity analyses (hand calculations, different idealizations, different discretizations, multiple methods)
- Error estimation and adaptive mesh refinement tied to solid geometry models

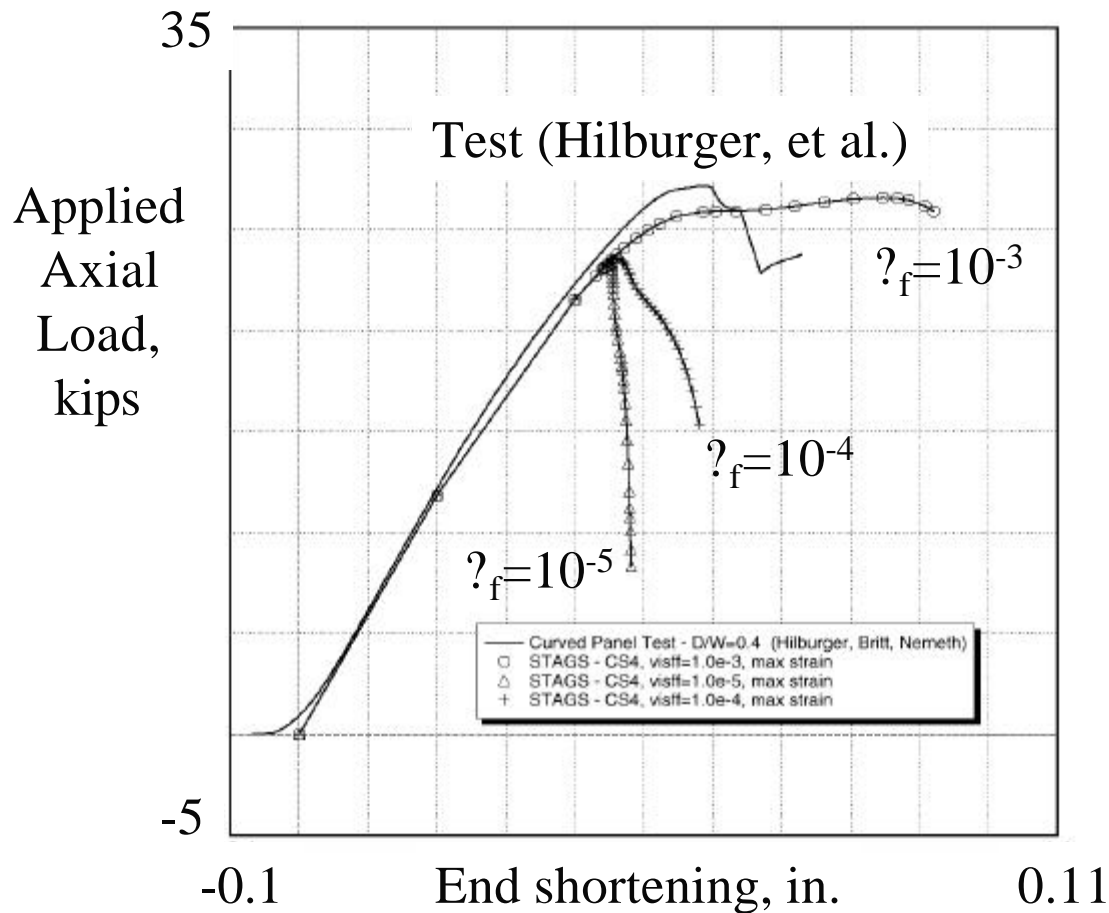
Mechanics - Solution Technology

- Growing need for hybridized solution procedures for quasi-static and transient dynamic simulations
- Quasi-static/transient procedures for collapse and mode-jumping problems
- Explicit/implicit transient procedures for long duration transient simulations
- Hybrid direct/iterative solvers for algebraic systems
- Hierarchical modeling and analysis procedures leading to high-fidelity simulations
 - p-version technology; shell-solid transitioning; homogeneous to heterogeneous material modeling

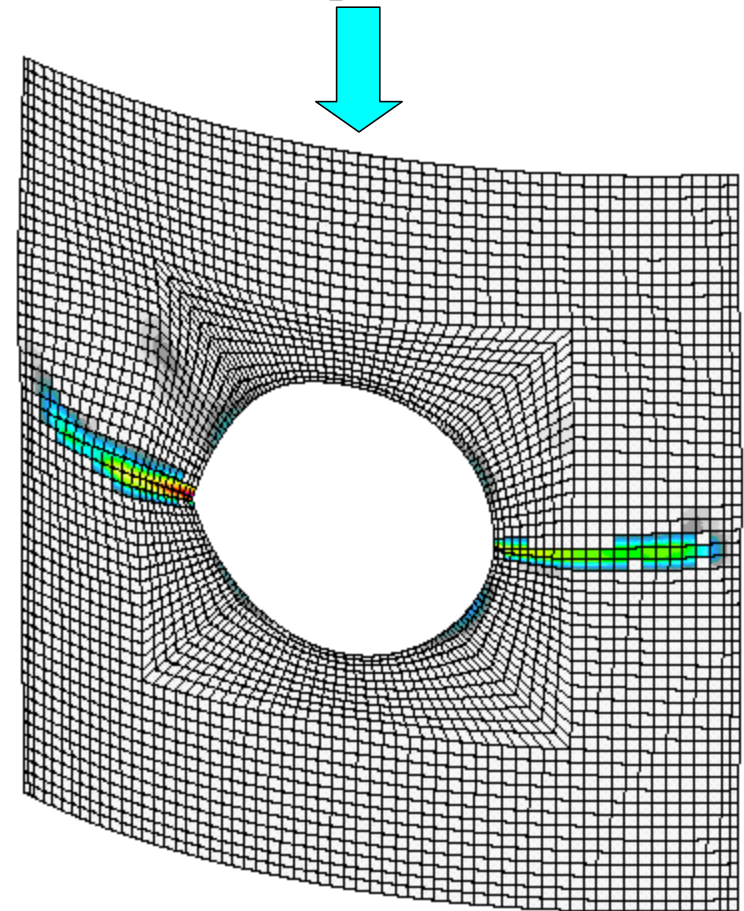
Composite Curved Panel with Cutout

- $D/W=0.4$, 16-ply quasi-isotropic panel -

STAGS Progressive Failure Analysis



Axial Compression Load

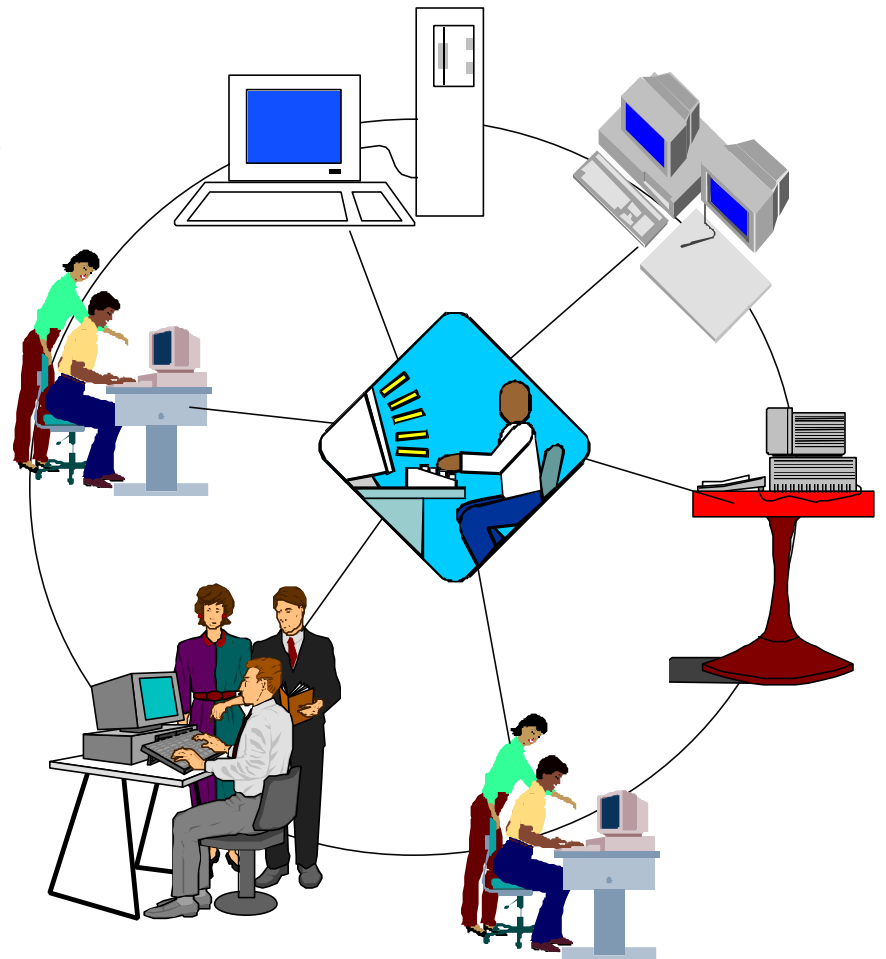


Computational Challenges

- Computer hardware (CPUs, memory, storage) is faster than ever and getting even faster
- Solver technology for large systems of equations continues to improve
- Adaptivity at the model level and at the solution procedure level provides measure of robustness
- Networked computing harvesting provides source for distributed concurrent computing
- Immersive technology for visual and auditory senses place increased demands on computing infrastructure

Emerging Paradigm for Computing

- Systems such as Condor for CPU-cycle scavenging for high-throughput resource management
- GUI-based interfaces for parametric studies coupled with uncertainty models and/or optimization procedures (e.g., ILAB/Ames)
- Typically co-located but potentially geographically dispersed using heterogeneous computing systems



Risk-Based Design Challenges

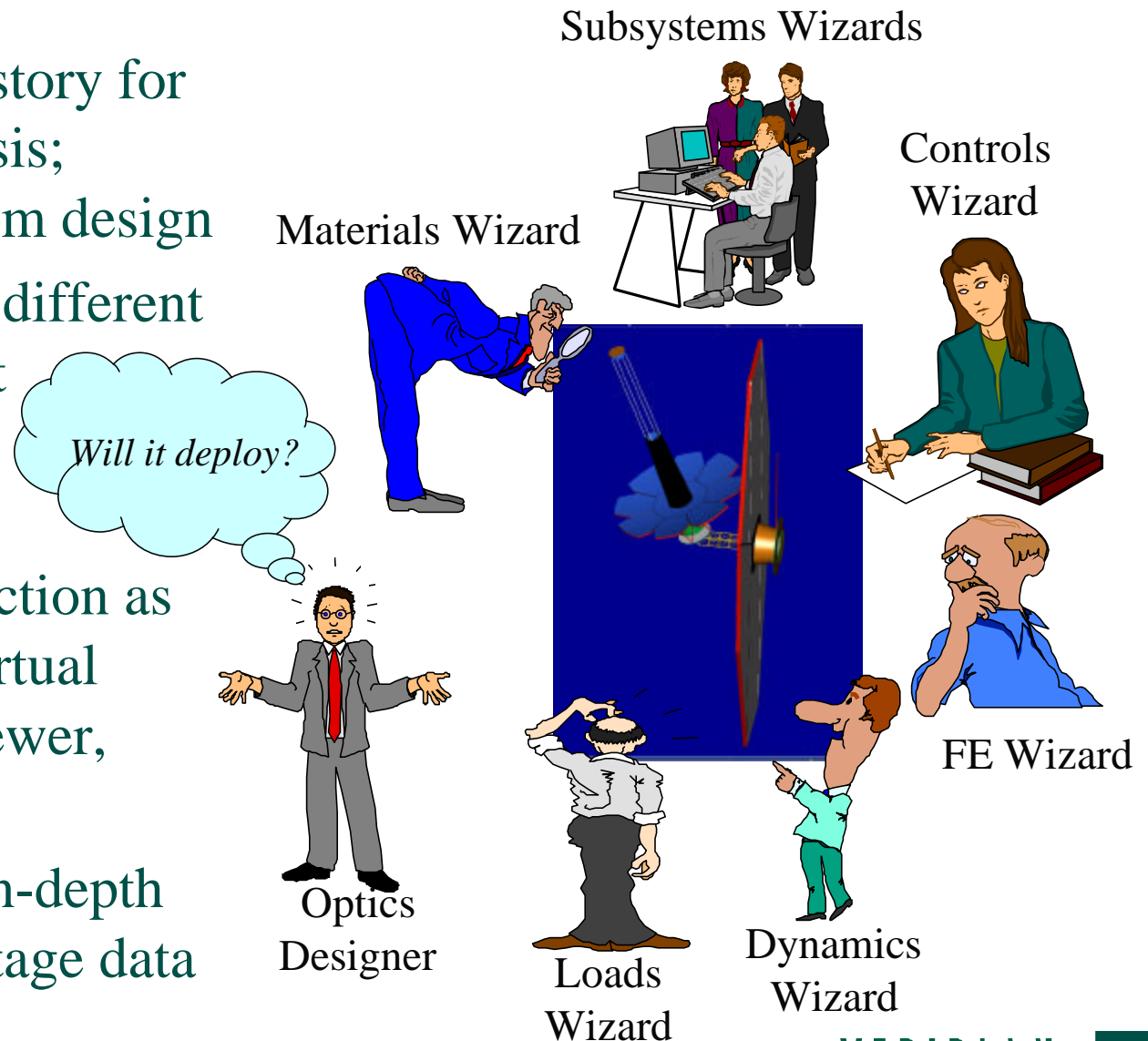
- Deterministic methods to assess uncertainties through probabilistic procedures, fuzzy logic models, Monte Carlo simulations
- Non-deterministic methods
- Scenario-based probabilistic risk assessment for the mission, vehicle, component, or subcomponent
 - Event-sequence diagrams, event-tree models, and linked-fault-tree models to estimate probability of mission success and to identify most significant failure sequences
 - Requires system-level knowledge, heritage data, quantifiable bounds for design trade-offs

Decision Making

- Advancements in design and analysis tool capabilities tend to run ahead of analyst in terms of:
 - Underlying mechanics principles
 - Enormity of computed results
 - Speed of generating results
- Integration and interrogation of vast amounts of information necessitate the need for methodologies to “mine” data or to guide the simulation
- Intelligent agents within an evolving knowledge basis are needed to augment the engineer in the loop

Intelligent Agents - “Wizards”

- Virtual corporate history for modeling and analysis; system and subsystem design
- Different agents for different disciplines, different methods, different systems/subsystems
- Collaborative interaction as virtual colleague, virtual mentor, virtual reviewer, virtual critic
- Provides access to in-depth knowledge and heritage data



Potential Features of Future Rapid Modeling and Analysis Tools

- Solid-geometry-based with idealization attributes
- Automated spatial discretization with interfaces to multiple methods
- Constitutive modeling for advanced materials accounting for damage in a hierarchical manner
- Generalized imperfection definitions
- Uncertainty measures and sensitivity derivatives
- Advanced computational tools and related interfaces for concurrent and parallel computations
- Advanced interrogation tools including “wizards”

Summary

- Many technical challenges remain
- Advances in computing infrastructure provide enormous potential to simulate structural behavior
- Advances in computing infrastructure provide enormous pitfalls for the unprepared analyst
- Increasing responsibility on analyst to insure the physics are captured accurately by the simulation
- Capturing corporate knowledge and providing system-level knowledge base is critical to risk mitigation

Closing Remarks

“...There is nothing so wrong with analysis as believing the answer! Uncertainties appear everywhere in the model...” (Richard Feynman in *What Do You Care What Other People Think*, Bantam Books, NY, 1988)

“Never before have we been able to compute the wrong answer so fast”

“The model looks like the part; it ran to completion on a supercomputer without errors; the results are displayed in color - how could they be wrong?”

“The purpose of computing is insight, not numbers.”